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December 1994

CONSTRUCTION PRODUCTIVITY ADVANCEMENT RESEARCH (CPAR) PROGRAM

Development of the Mechatronically Assisted Mason's Aide

by

Orange S. Marshall, Jr.

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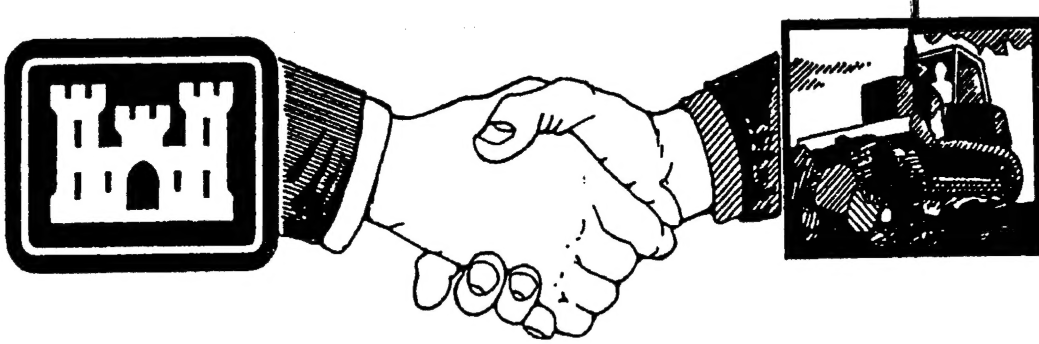

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13. ABSTRACT (Maximum 200 words)

This report describes the development of a mechanical assisted device to facilitate the lifting and placing of masonry block by masonry construction workers. A mechatronically assisted mason's aide (MAMA) was developed as a cooperative effort between the U.S. Army Construction Engineering Research Laboratories and the International Masonry Institute. MAMA uses robotic technologies to enhance the productivity of masonry craftsmen and thus alleviates injuries associated with lifting and handling heavy masonry units. MAMA is an article manipulator system that mounts on mast type scaffolding making it capable of alignment compensation for scaffold nonalignment, limited movement about two vertical axes, and a generally horizontal movement along a trolley track parallel to wall construction. MAMA has a gripper for grasping heavy objects such as concrete masonry units and a control handle for raising and lowering a lift cable and for locking and unlocking brakes on the pivot arms and trolley track.

A prototype unit was constructed and field tested, and was presented at an international masonry union conference and training seminar. Feedback from the field test and the conference/seminar will be part of the production engineering for MAMA. It is estimated that it could be available for concrete masonry construction by April 1996.

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Foreword

This study was conducted for Headquarters, U.S. Army Corps of Engineers under the Construction Productivity Advancement Research (CPAR) work unit "Mechatronically Assisted Mason's Aide," Funding Authorization Document (FAD) 1-002443, dated 27 September 1989. The technical monitor was Charles H. Gutberlet, Jr., CEMP-ET.

The work was conducted by the Engineering and Materials (FM) Division of the Infrastructure Laboratory (FL), U.S. Army Construction Engineering Research Laboratories (USACERL) and the International Masonry Institute (IMI). The USACERL Principal Investigator is Orange S. Marshall, Jr., CECER-FMS, and the IMI Principal Investigator is John P. Eberhard. Dr. Paul A. Howdyshell is Chief of USACERL-FM.

Special acknowledgment is due to Thomas Mahan, Debbie Lawrence, and LTC Thomas J. Kelly, all former USACERL principal investigators for the MAMA project, for their input and guidance for the project in its early stages. Special acknowledgement also is due to Advanced Technology and Research (ATR) of Laurel, MD, which performed early concept development for the gripper, and to Riley H. Mayhall, Jr., and M&M Consulting, Inc. of Burtonsville, MD, who did the detail design and fabrication of the MAMA prototype.

LTC David J. Rehbein is Commander and Acting Director of USACERL. Dr. Michael J. O'Connor is Technical Director.

Contents

SF 298 1

Foreword 2

List of Figures 4

1 **Introduction** 5
Background 5
Objectives 6
Approach 6
Mode of Technology Transfer 7

2 **MAMA Description** 8
Description 8
Operation 10

3 **Development of the MAMA Prototype** 22
Project Definition 22
Project Development 22
Prototype Production 23
Prototype Field Test 23
Prototype Demonstration 25

4 **Production and Marketing Plans** 26
Preproduction Plans 26
Production Plans 26
Marketing Plan 26
Expected Capabilities and Benefits of MAMA 27

5 **Conclusions and Recommendations** 28
Conclusions 28
Recommendations 28

Appendix A: MAMA Design Operational Capabilities and Performance Criteria . . . 29

Appendix B: Scope of Work for Robotically Assisted Masonry Construction 30

Distribution

List of Figures

Figures

1	The mechatronically assisted mason's aide (MAMA)	12
2	MAMA	12
3	MAMA scaffolding mounts (two vertical steel reinforcements, nonpainted, on either side of masts)	13
4	Trolley track assembly	14
5	Trolley track slip joint	14
6	Trolley assembly with manual brake override, track wheels, and power pick-off	15
7	Trolley assembly	15
8	Manipulator assembly (a)	16
9	Manipulator assembly (b)	16
10	Gripper assembly (a)	17
11	Gripper assembly (b)	17
12	Operator control handle	18
13	Power control assembly	18
14	Transformer package	19
15	Trolley track mount and pin connectors	20
16	Trolley track pin connectors	21

1 Introduction

Background

The masonry industry is one of the major construction industries in the United States. It represents an estimated $13 billion in annual business volume, of which 40 percent is for direct labor costs, 40 percent for materials, and 20 percent for overhead and profit of contractors who work on the site.

Masonry construction has a long history of strained backs and injuries for the skilled masons who build with brick, block, stone, and marble. As the average age of craftsmen advances (it now approaches an average working age of 55), there is an unfortunate but parallel increase in the weight (and often the size) of manufactured concrete masonry units (CMUs). The industry has experienced rapid increases in recent years in the cost of workers' compensation insurance due in large measure to back strain and injuries. Awards for back injuries on the job have been as high as $3 million per individual worker.

The productivity of this sector of the construction industry in the United States would be greatly enhanced if one or more devices could be developed to alleviate the skeletal and muscular strains and injuries associated with lifting heavy units. "Extraskeletal" robotic devices have been experimented with in military research programs to enhance the lifting capabilities of service members for handling munitions and other heavy objects. Developing a prototypical device for use by masonry workers and providing field tests for the prototype based on the technological transfer of military robotics work to the masonry industry will benefit both the construction industry and the individual masons who build with brick, block, stone, and marble.

To pursue the development of a robotic lifting device and transfer the technology to the masonry construction industry, a partnership was established in March 1990 between the U.S. Army Construction Engineering Research Laboratories (USACERL) and the International Masonry Institute (IMI) under a Construction Productivity Advancement Research (CPAR) Program Cooperative Research and Development Agreement (CRDA) of the U.S. Army Corps of Engineers.

IMI is the ideal choice for partnership in this work because of its unique standing in the construction industry. IMI was founded in 1970 as an instrument of service to union contractors and craftsmen in masonry and for advancing the interests of masonry. Funded by masonry contractor and union member contributions determined by the collective bargaining process, it continues to reflect the specialized character and needs of this industry. IMI constituency includes the 98,000 members of the International Union of Bricklayers and Allied Craftsmen (BAC) and the 7,000 firms that use their skills (organized through the International Council of Employers of Bricklayers and Allied Craftsmen [ICE]). The Apprenticeship and Training Program of the IMI is an addition to (not a replacement for) the efforts of some 500 locals of the BAC. These programs operate through five regions in the United States and Canada, and, with the support of the Agency for International Development, in Central America.

Objectives

The objectives of this work were to develop a mechatronically assisted mason's aide (MAMA) that would (1) reduce human musculoskeletal strains and injuries in the mason population in the United States and the associated costs that result from current masonry wall construction practices; (2) reduce the most strenuous of manual lifting procedures and comply with all current and projected Occupational Safety and Health Administration (OSHA) regulations required in current masonry wall construction practices; and (3) provide the optimization/blending of current technologies and emerging technologies, hybridizing them and their concurrent reductions to practice.

Approach

The project was organized around three phases: project definition, project development, and prototype production and testing. During the project definition phase, the partnership team undertook a matrix analysis of the problem areas for masonry craftsmen and cross-referenced known technologies that might be applied. A cost benefit analysis was used to assess which technologies showed the most likely quick paybacks and associated benefits in terms of the productivity of this sector of the construction industry. The project development phase integrated design aspects of the USACERL Explosive Ordnance Disposal robot and the Mississippi River revetment automation into a concept design for MAMA, and a prototype design was selected. The design was evaluated using computer simulation, and final prototype designs and specifications were developed. The prototype production and testing phase produced

a working prototype of the selected device. Field tests of the device were conducted using union masons. Patent applications were prepared and processed, and needed adjustments to the device were incorporated into final prototype designs.

Mode of Technology Transfer

Technology transfer of MAMA will be through USACERL Ad Flyers and fact sheets, presentation of technical papers at robotics and masonry industry conferences, and patent publications. IMI will transfer the technology through demonstrations, licensing, and sales agreements with manufacturers, its Apprenticeship and Training Program, and advertising via union masonry contractor organizations associated with IMI.

2 MAMA Description

MAMA is an electromechanical device that is designed to alleviate skeletal and muscular strains associated with lifting and handling heavy masonry units. It is intended for use in the masonry industry for active human controlled manipulations of concrete block work pieces during the construction of masonry walls and other projects. MAMA was designed especially for use when the weight of the work pieces exceeds what a human can easily handle or that is permissible by governmental regulations. The design requires that MAMA be used in combination with existing work place configurations of equipment and mast-type scaffolding. Appendix A lists the required operational capabilities and performance criteria for the MAMA prototype design.

Description

MAMA is a robotically assisted manipulator consisting of scaffolding mounts, a transformer package, and assemblies for a trolley track, a trolley, a manipulator, a gripper, and a power control. They attach together and form a suspended crane-like device that attaches to mast-type scaffolding (Figures 1 and 2*).

Scaffolding Mounts

The scaffolding mounts are steel frame structures that serve several purposes. Their main purpose is to attach MAMA to the scaffold masts. In doing this, they securely fasten each trolley track section to the scaffolding, suspend MAMA out over the work area for easier work item manipulation, and reinforce the scaffolding to overcome any bending moments introduced by MAMA during construction operations. Due to variations between manufacturer designs in mast-type scaffolding, MAMA requires slightly differing mount designs. The design depicted in Figure 3 attaches to Morgan Scaffolding, which was used in prototype field tests.

* Figures can be found at the end of this chapter.

Trolley Track Assembly

The trolley track assembly (Figure 4) is used to provide lateral mobility for MAMA along the length of a scaffold assembly. It is made from extruded aluminum and has an electrically isolated power transmission bar incorporated into it. The track is designed to be modular so the track length is not restricted and for ease of assembly. Because scaffolds are not erected with precision, sufficient mechanical allowance is made for misalignment of scaffold assemblies. The misalignment is compensated for by allowing the trolley track to extend in a horizontal direction and bend or twist at each scaffold support point (Figure 5). This capability is especially important when one section of scaffold is raised while another section remains stationary.

Trolley Assembly

The trolley assembly (Figures 6 and 7) mounts inside the trolley track on four wheels. It includes the electrical power pick offs, locking brakes for the system, and cable routing. It gives MAMA power and mobility.

Manipulator Assembly

The manipulator assembly consists of a double-jointed pivot arm (Figures 8 and 9) and steel wire cable to enable an operator to position the gripper assembly vertically over work pieces for lifting, moving, and placing the blocks during wall construction. It is designed to allow access to blocks that may be stacked on scaffolding and economically move them to the wall being constructed. It includes the hoisting cable and cable take up as well as brakes for both the pivot arm and the lifting cable.

Gripper Assembly

The gripper assembly (Figures 10 and 11) is the interface between MAMA and the block mason. The gripper consists of an operator control handle (Figure 12) with an integrated dead man switch, a brake release used in repositioning MAMA on the trolley track, and a gripping mechanism for grasping concrete block webs attached to the gripper mount. The gripper mount contains a series of mounting holes near the top that the gripping mechanism mounts through with a steel pin. These holes allow the user to compensate for variations in the center of gravity caused by asymmetrical block designs.

Power Control Assembly

The power control assembly (Figure 13) is the brain for MAMA. It contains the computer controls for the entire system. A microprocessor provides for selective locking and unlocking of pivot arm sections, trolley track brakes, opening and closing of gripper jaws, and response to operator commands received from the operator control handle on the gripper.

A dead man switch is incorporated into the operating system so, if an operator releases the handle, all braked axes are locked, and the trolley track brakes are locked. In addition, the gripper jaws are locked on any item being picked up, and the hoist assembly is locked. The dead man switch, when released, causes the entire assembly to lock up, thereby preventing injury to a human worker.

The microprocessor monitors the load on the gripper assembly. It is set to limit the weight MAMA will lift to 150 lb. If someone tries to lift a load greater than 150 lb, MAMA will not provide any lifting power.

Transformer Package

The transformer package is a standard electrical transformer box that converts 110 Volt alternating current (AC) into the 28 Volt direct current (DC) required for MAMA (Figure 14).

Operation

The first part of the MAMA operation is to assemble it. The prototype is assembled by first attaching the scaffold mast reinforcing bars and the mounting brackets to each mast using hex bolts. After the reinforcing bars and mounting brackets are attached, the scaffold mast is erected in its normal manner at the construction site. The trolley track sections then can be attached to the mounting brackets using pin connectors (Figures 15 and 16). MAMA is lifted using a fork lift and mounted on the trolley track, and the DC power is attached to the track. MAMA is ready for use when the power is turned on.

With the power turned on, the trolley can be repositioned by first holding the operator control handle to release the dead man release and unlocking the pivot arm brakes. The pivot arm is moved to a position convenient for moving the trolley. With the dead man button depressed on the operator control handle, the move button on the gripper assembly is depressed. The move button locks the pivot arm and releases the trolley

brake. The trolley then can be pulled easily to the desired position along the wall. When the move and dead man buttons are released, the trolley brake is engaged and MAMA is ready for work.

After the trolley is positioned at the work location, the user must guide the gripper to the CMU pick up position. Typically the CMU are stacked on the scaffold or on a pallet on the scaffold. By applying a downward force on the operator control handle, the gripper is lowered to pick up a block. Plastic guides are attached to the gripper to ease in centering the gripper in a block. The gripper is lowered until it rests on the block. When the gripper is on the block, the operator control handle is moved to the neutral position, and a button on either end of the handle is pushed to close and open the gripping mechanism. (The operator control handle must be in the neutral position to activate or deactivate the gripping mechanism.) When the mechanism is closed, applying an upward force on the operator control handle raises the gripper assembly and the CMU. While gripping the operator control handle, the operator can swing the CMU to the working position and lower it by pressing down on the handle. During wall construction, mortar is applied to the CMU as needed while it is being lowered into position. The operator continues to lower the CMU until it is seated in position and the cable goes slack. When the cable is slack, the operator presses the button on the end of the operator control handle causing the gripper mechanism to release the block. Then by applying upward force on the handle, the gripper is lifted free of the block and is ready to place the next block.

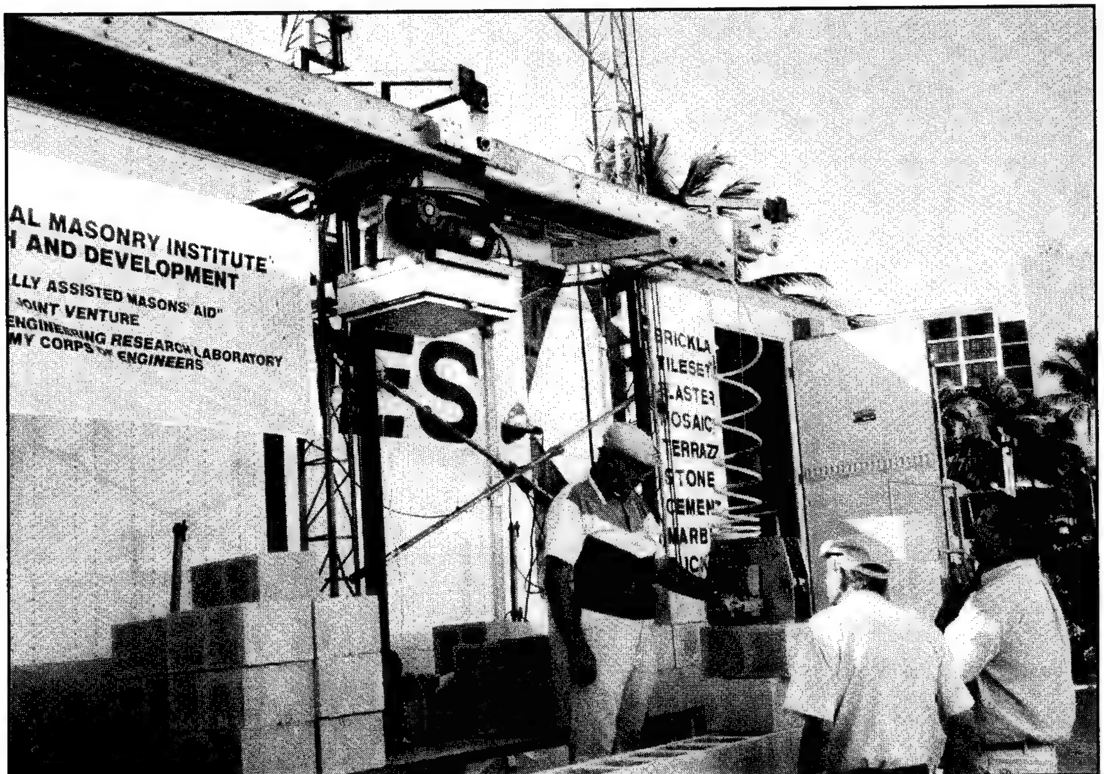

Figure 1. The mechatronically assisted mason's aide (MAMA).

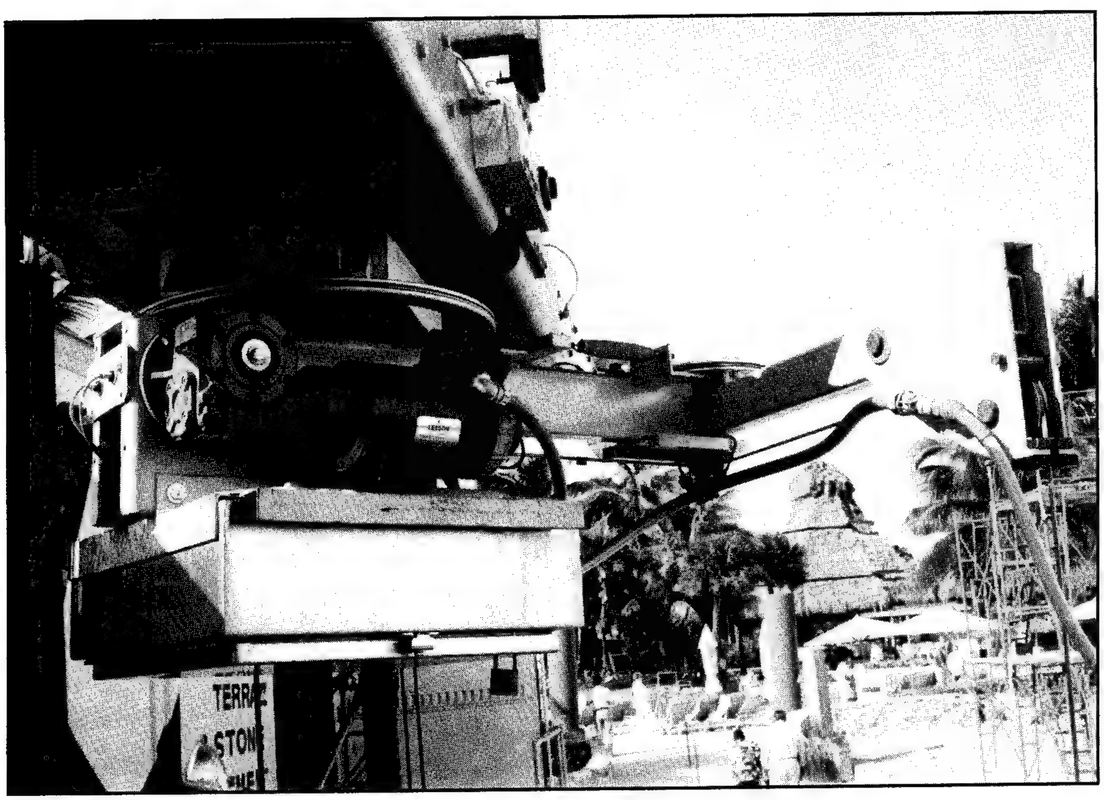

Figure 2. MAMA.

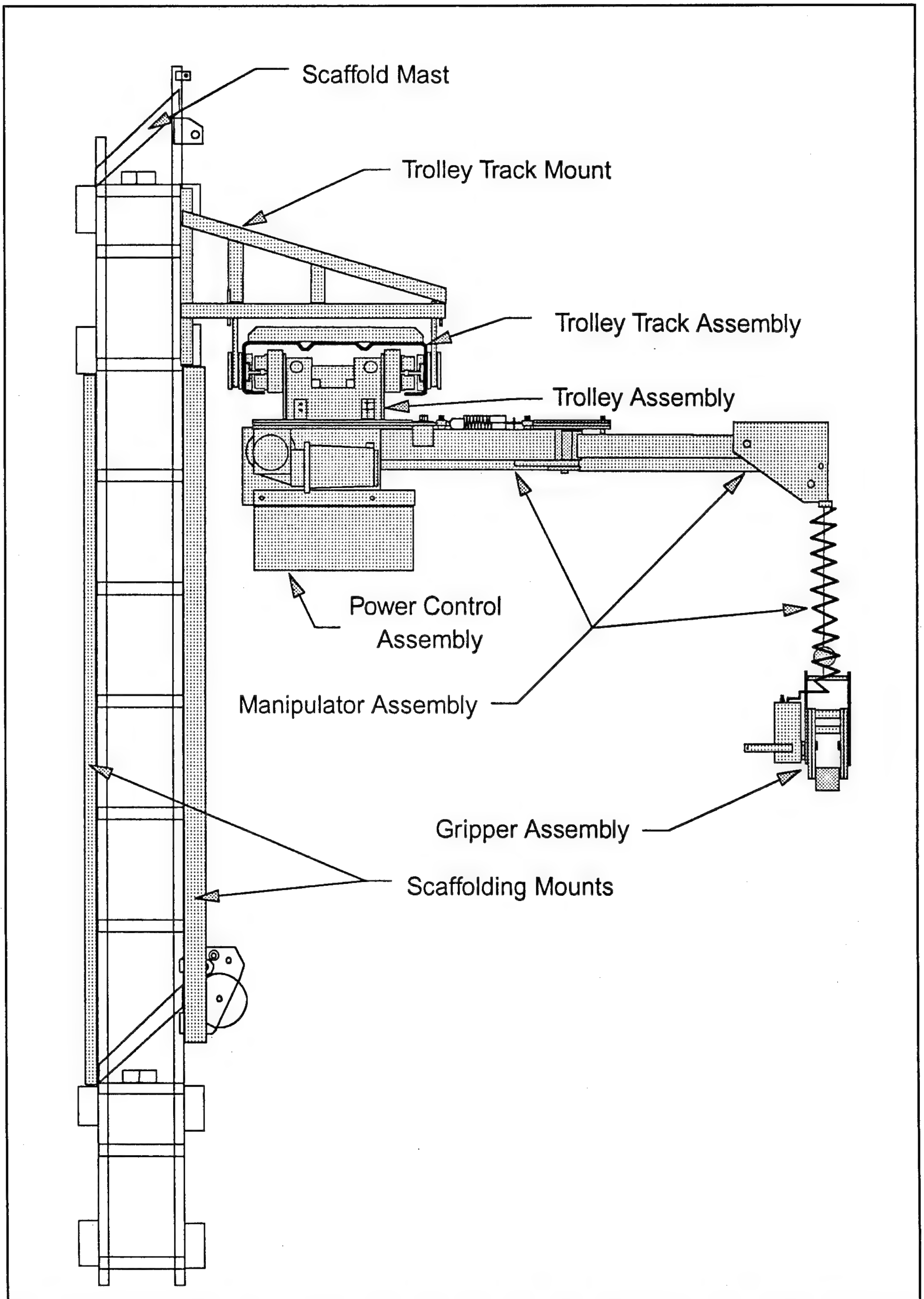

Figure 3. MAMA scaffolding mounts (two vertical steel reinforcements, nonpainted, on either side of masts).

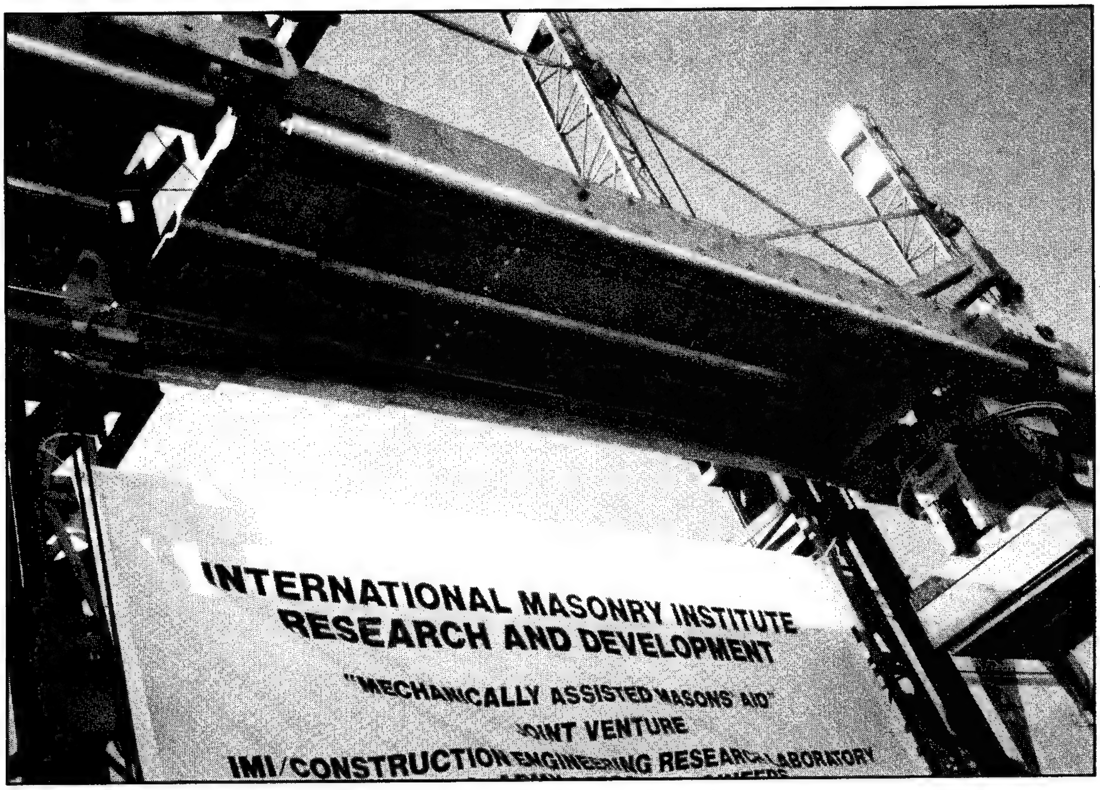

Figure 4. Trolley track assembly.

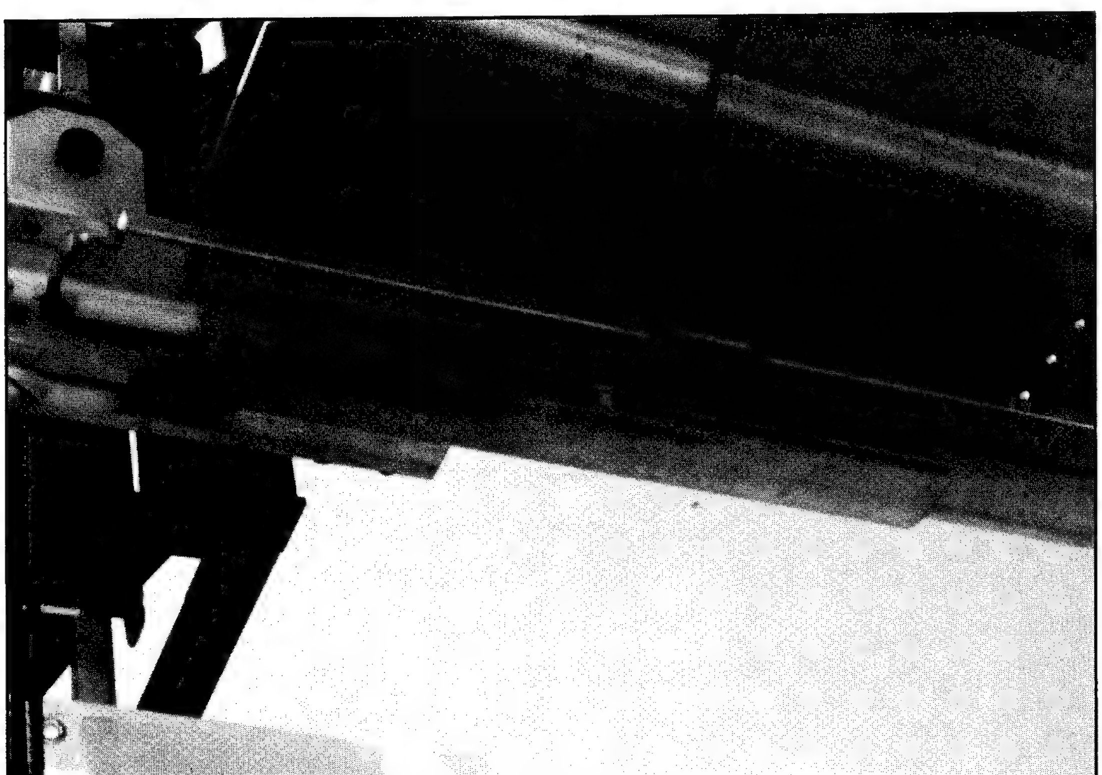
Figure 5. Trolley track slip joint.

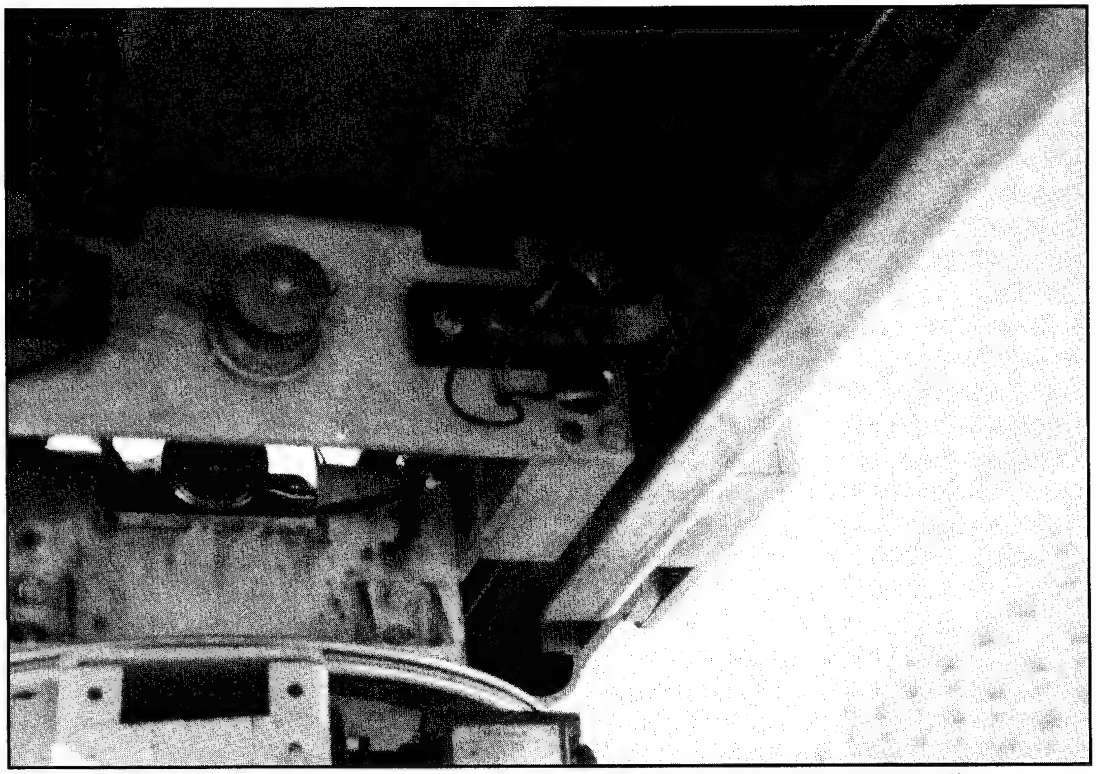

Figure 6. Trolley assembly with manual brake override, track wheels, and power pick-off.

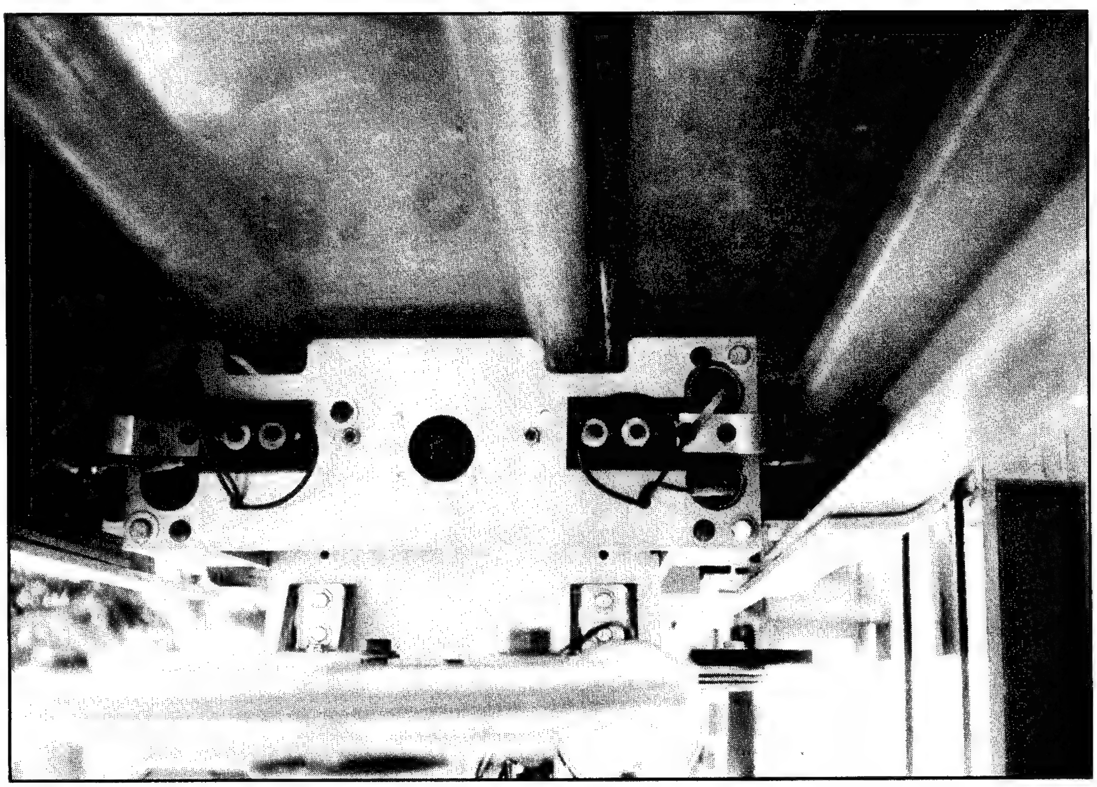

Figure 7. Trolley assembly.

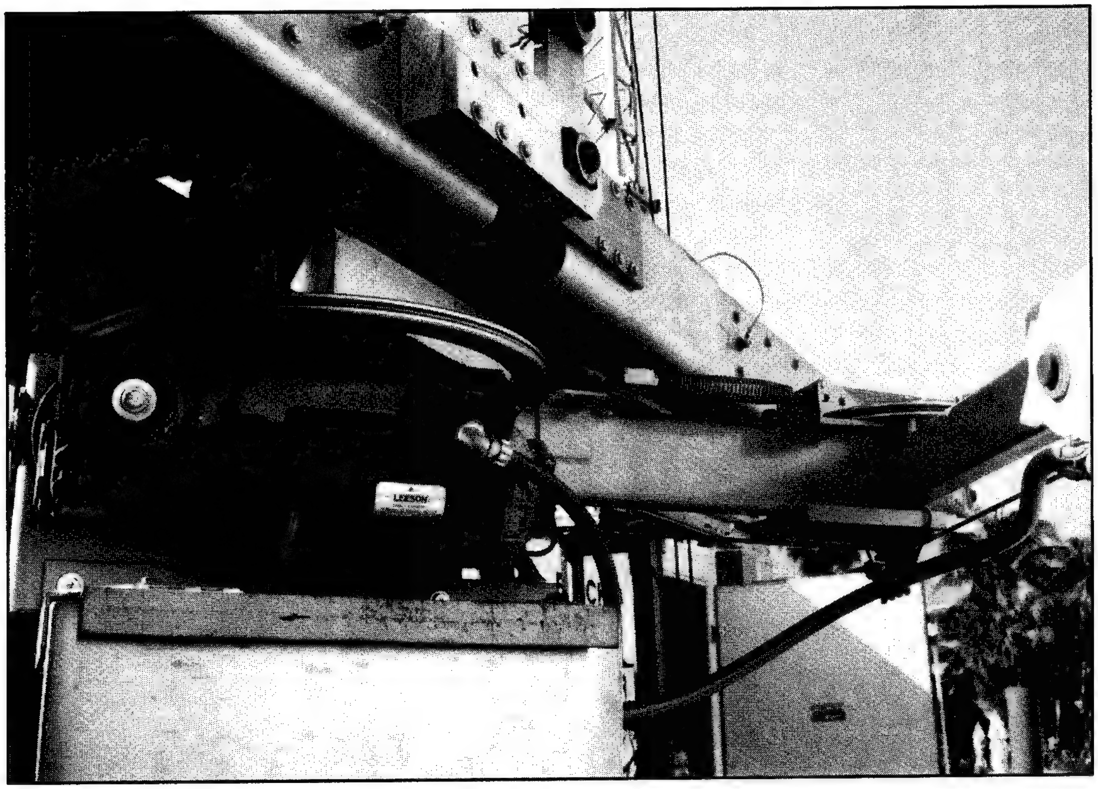

Figure 8. Manipulator assembly (a).

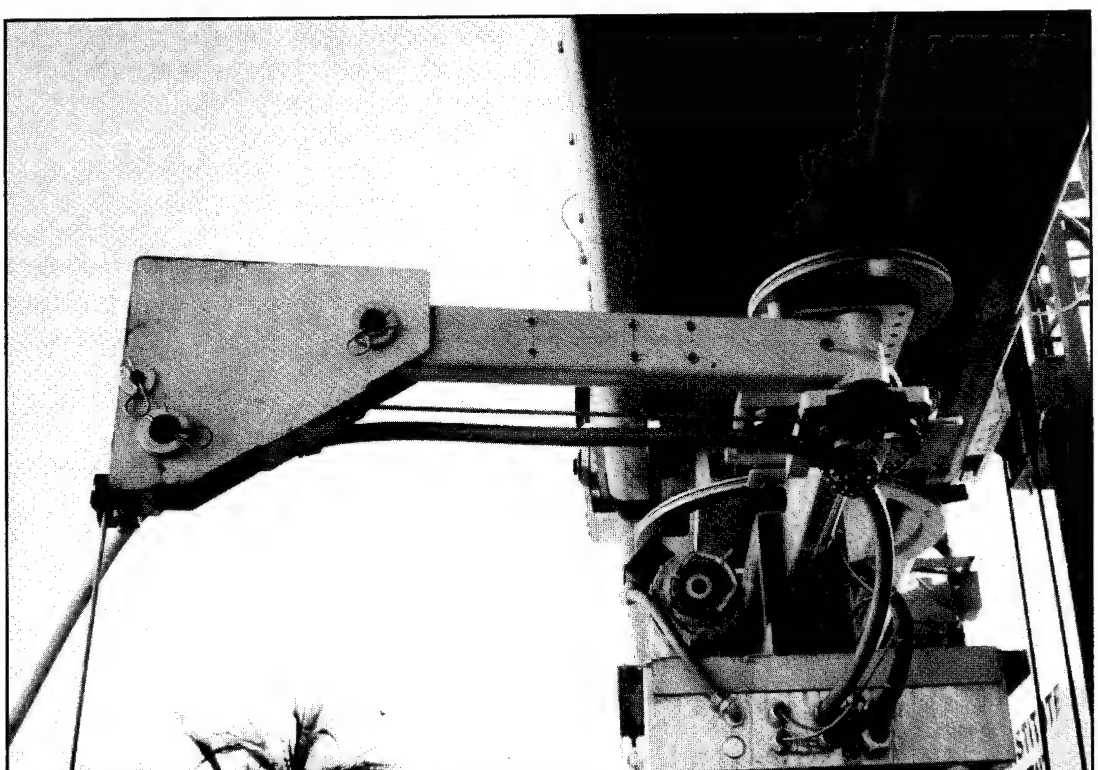

Figure 9. Manipulator assembly (b).

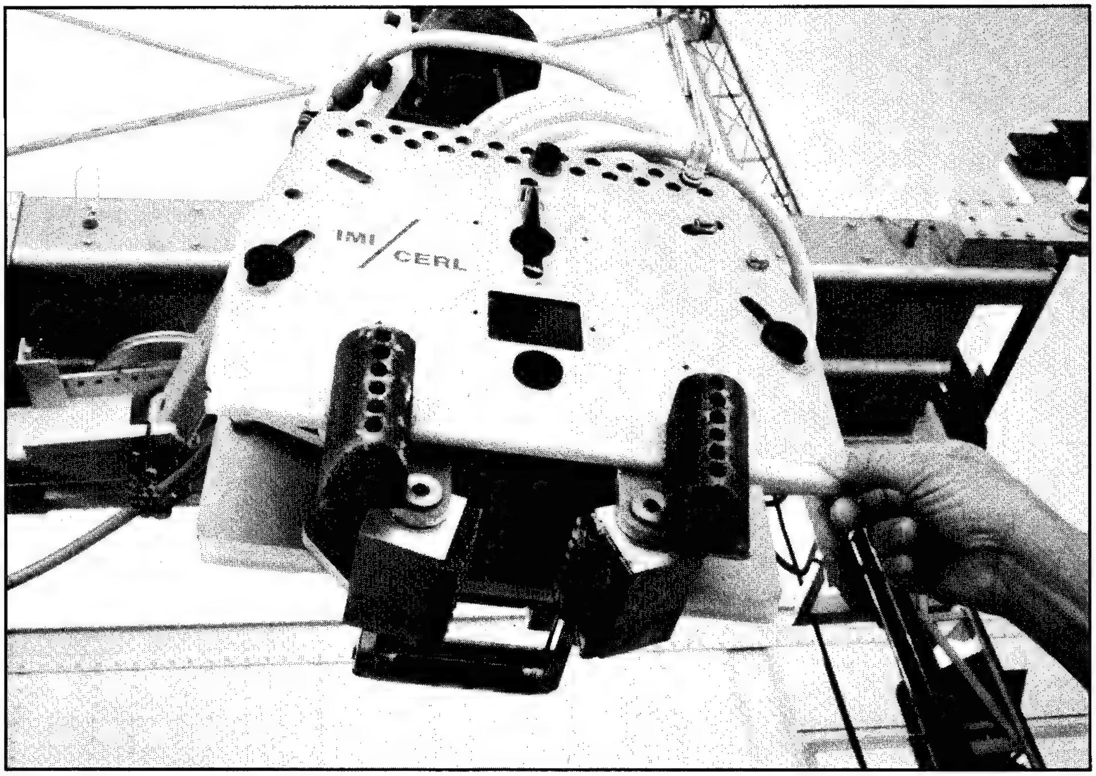

Figure 10. Gripper assembly (a).

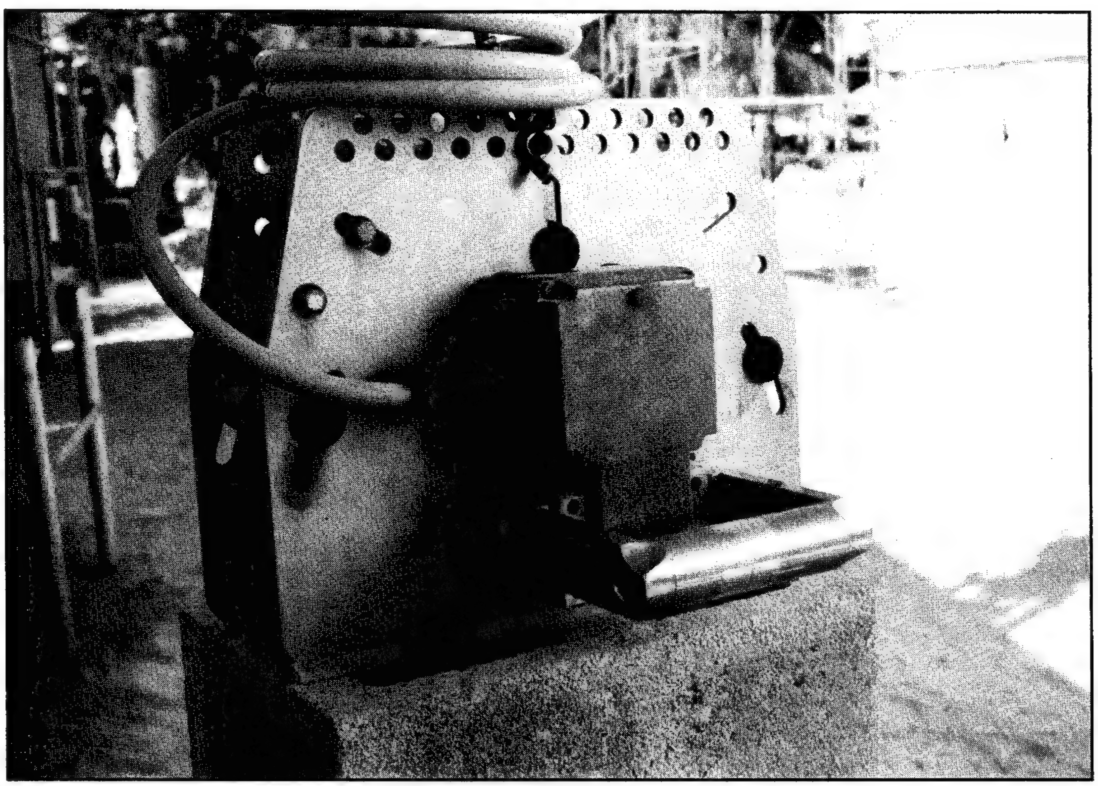
Figure 11. Gripper assembly (b).

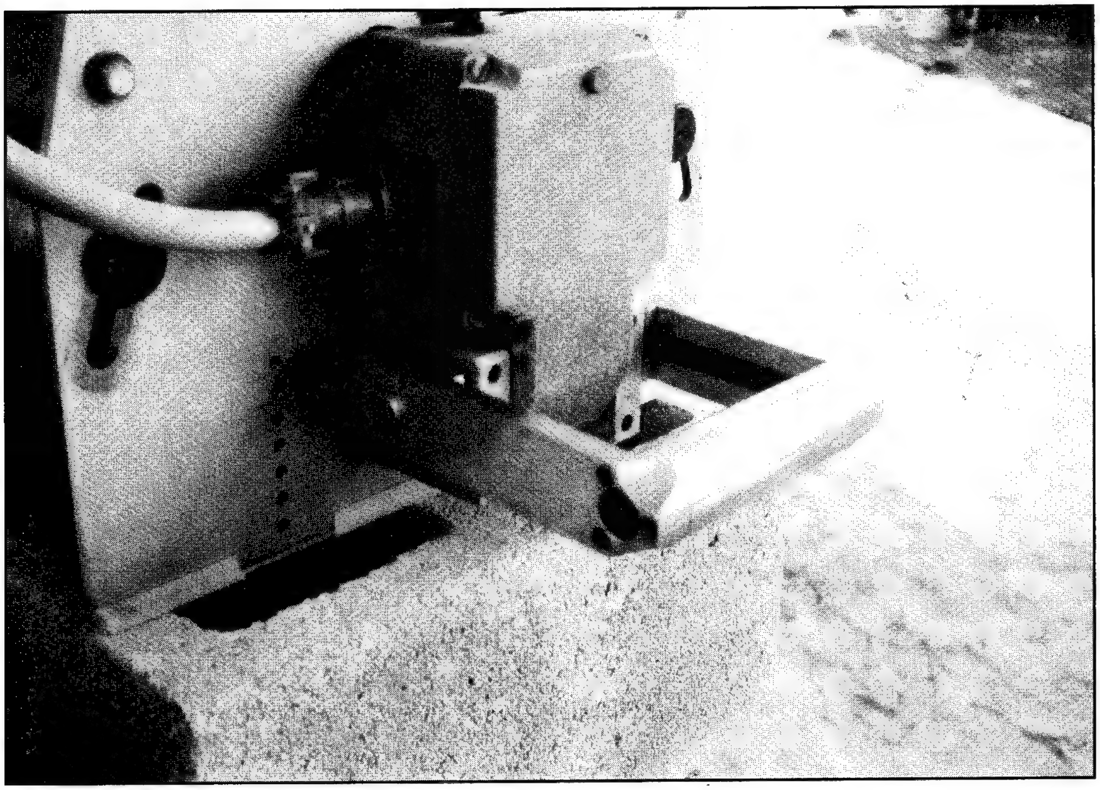

Figure 12. Operator control handle.

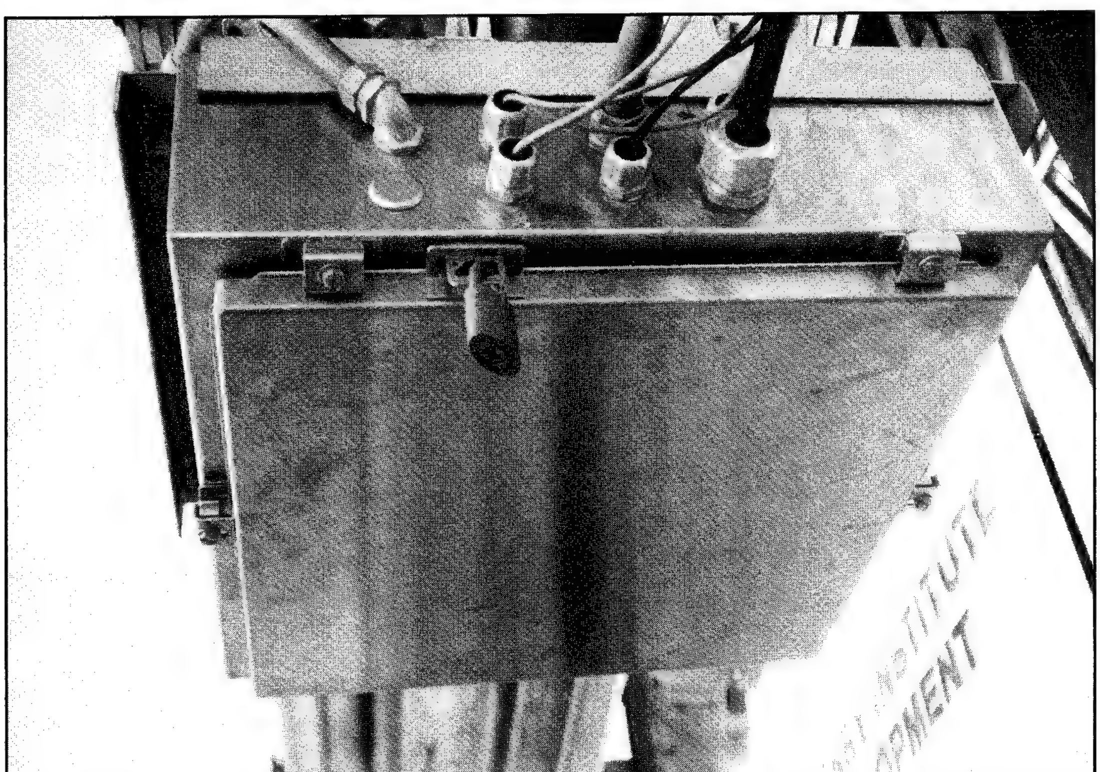

Figure 13. Power control assembly.

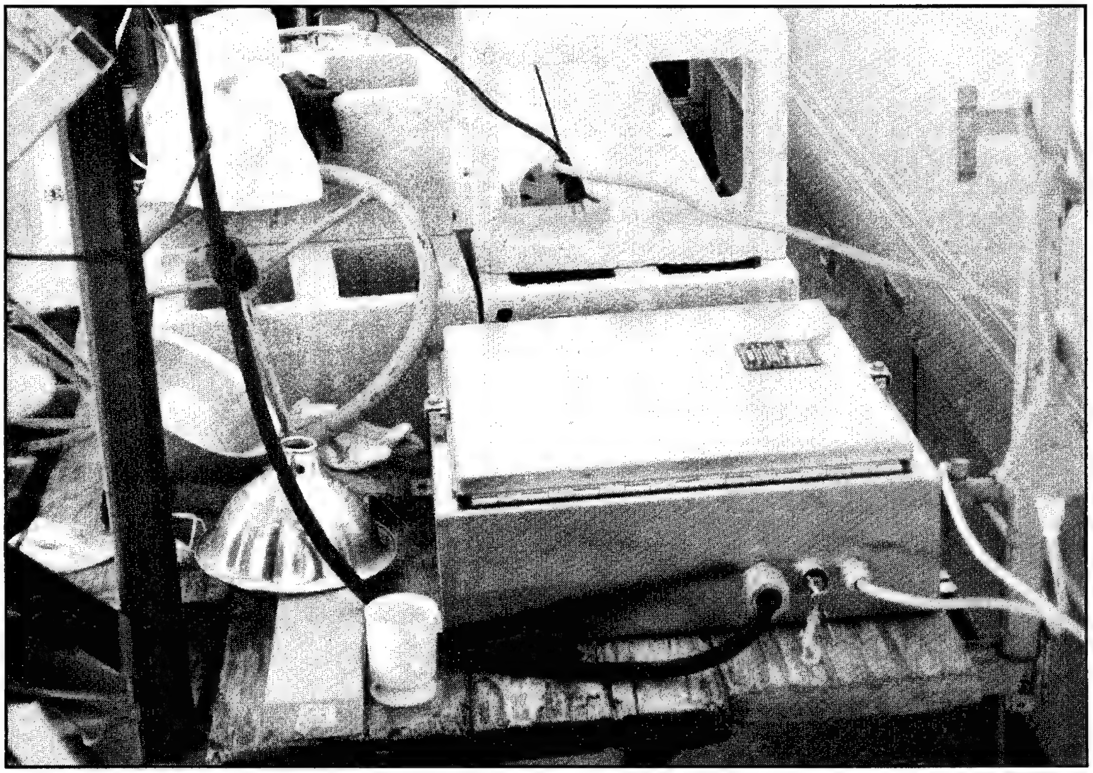

Figure 14. Transformer package.

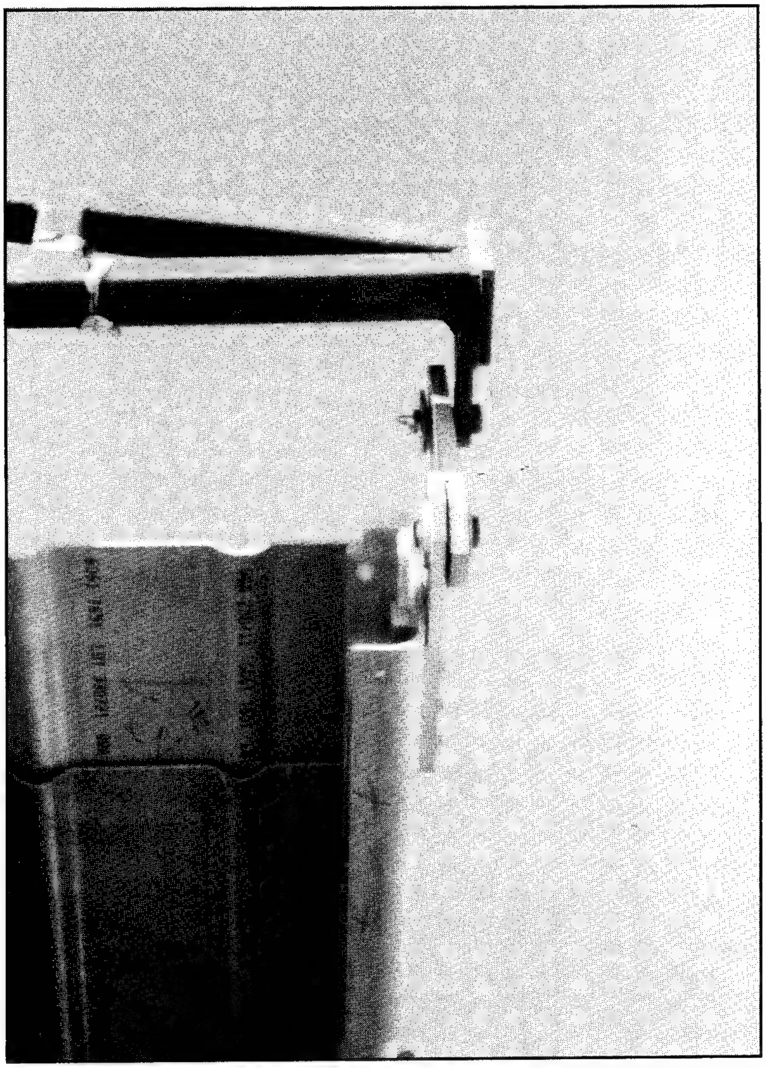

Figure 15. Trolley track mount and pin connectors.

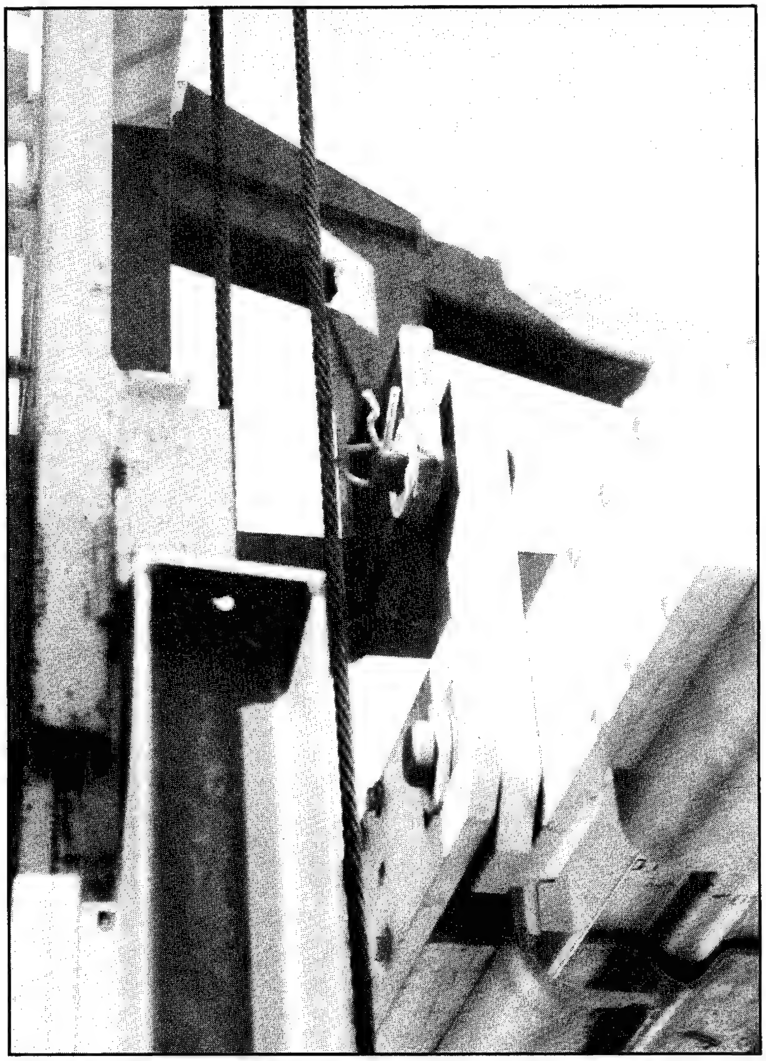

Figure 16. Trolley track pin connectors.

3 Development of the MAMA Prototype

The development of the MAMA prototype was organized around three phases: project definition, project development, and prototype production and testing. Appendix B details the scope of work for this project.

Project Definition

A "partnership" was formed at the beginning of the project definition phase and consisted of three representatives of IMI and three technically qualified persons selected by CERL. The team was co-chaired by the principal investigator for IMI and the principal investigator for USACERL. During this phase the partnership team undertook a matrix analysis of the problem areas for masonry craftsmen, in terms of performance criteria and health and safety requirements, and cross-referenced known technologies that might be applied. Only those technologies that had already advanced to the application stage were considered, as opposed to scientific developments or hypothetical technologies.

A cost benefit analysis was used to assess each of the identified technologies that showed the most likely quick paybacks and associated benefits in terms of the productivity of the masonry industry. The goal of the partnership was to develop an "extraskeletal" robotic device that could be "worn" by a mason to assist in the lifting of units of up to 100 lb with reduced muscular strain. It was determined early in the project that an extraskeletal device worn by the masons on high scaffolding would restrict their movement too much and increase the risk of falling, so the MAMA design goal was modified to reflect a safer alternative.

Project Development

The technical development phase was performed by USACERL in conjunction with private industry. IMI provided ergonomic and technical data about a variety of field conditions to which the eventual devices might be subjected (working on scaffolding 150 ft in the air with 30 mile per hour [mph] winds, OSHA regulations, etc).

Preliminary designs (on paper) of alternative devices were evaluated by the members of the USACERL/IMI partnership. A prototype design was selected from the partnership evaluation, and an evaluation of the design was conducted using computer simulation. The purpose of the simulation was to test and evaluate the motion requirements and restrictions for the selected design so necessary modifications could be made before prototype development. Technical discussions were held with masonry contractors and concept designers to review the prototype design and economic feasibility. Advanced Technology Research refined the MAMA concept by developing prototype drawings for the gripper and constructing a rudimentary gripper prototype. Final prototype designs and specifications were developed after additional refinements by the partnership.

Prototype Production

Based on the results of the project development phase, a contract was awarded to M&M Consulting, Inc., Burtonsville, MD, to produce a working prototype of the selected device. Patent applications were prepared and processed for the gripper, operator control handle, and the trolley/trolley track assemblies; and the final prototype was constructed.

Prototype Field Test

A field test of the MAMA prototype was conducted 21 and 24 October 1994 at the IMI apprentice training facilities near Harpers Ferry, WV. The test consisted of assembling MAMA at a construction site, testing the movement controls and safeties, and constructing a CMU wall using MAMA. Instructors from the apprentice training facility were used to test MAMA. The test consisted of checking the safety controls of MAMA and building a 30 ft long wall using 12-in. CMUs that weighed 44 lb each.

Three 12-in. CMUs were fastened together using mortar and allowed to set up. The inside of the blocks were filled with mortar. The resulting "block" weighed approximately 200 lb. To validate the load-limiting function of MAMA, an attempt was made to lift the fabricated block. The load sensors worked well, and MAMA would not lift them. A block was picked up, and the operator released the control handle to validate the dead man brake safety functions. They worked as designed. Work proceeded to construct a wall.

During the wall construction tests, a determination was made that one mason should operate MAMA while the another applied mortar and performed the final leveling/

positioning of the block after it was set down by MAMA. With the possible exception of laying the last block in a course, the laying of 12-in. blocks normally is a one-man operation; but two men were used for the field test . There was a short-term learning curve involved in coordinating the movements of the two masons. But their productivity quickly increased when the learning phase ended. Normal block laying production is 150 blocks per day per man. The production rate for a two man crew is 300 blocks per day or 37.5 blocks per hour. The masons laid the last two courses, 23 blocks, in a half hour using MAMA.

The masons using MAMA indicated they were impressed with the ease of lifting and placing the heavy blocks using MAMA. After laying four tiers of blocks, the masons stated that they were not nearly as tired as they normally would be after doing that amount of work.

A few minor difficulties were noted during the course of the field test. The major one was software related. The neutral detent position on the operator control handle was not wide enough, and the operators had trouble locating it some of the time. Another problem occurred when repositioning the trolley. The poorly defined neutral detent was a contributing factor to this problem. If the control handle is not in the neutral position, the brakes on the trolley assembly will not release. When the operator began pulling the trolley to a new position, the operator handle moved out of the neutral position and locked the trolley brakes. The dead man switch in the handle became partially unfastened and caused some operational delays. And, on one occasion, the operator had trouble pulling the trolley across a trolley track joint that was a little out of alignment.

The detent problem is software related and can be fixed by modifying the control program. The loose dead man switch can be repaired. The problem observed when pulling the trolley across the one trolley track connector may require a hardware modification. MAMA was initially designed so the trolley wheels would act as electrical pickups for the system. As such it has eight small wheels, four on each side, that it rides on so there would always be at least two wheels in contact with the power strip at all times. The design was recently modified to use a separate dedicated electrical pick off. As a result, the wheel design can be modified to use four larger diameter wheels. A larger wheel design will eliminate the problem encountered in the field test.

Prototype Demonstration

A demonstration of MAMA by IMI was planned for 18 November 1994 in Bal Harbor, FL, in conjunction with the annual business and training conference. MAMA was taken there 10 days before the meeting and set up on the beach to enable the demonstrators to practice and become proficient before the demonstration. Four days before the demonstration, tropical storm/hurricane Gordon arrived. The morning of the demonstration, the dead man control for MAMA operated erratically. This was believed to be the result of either corrosion caused by the storm or possibly moisture getting inside the control assembly. Responses from the control handle worked well at times and at other times did not work at all. As a result, MAMA was shown to the masons in attendance and the motions for laying block were demonstrated, but no actual wall construction was performed.

4 Production and Marketing Plans

The goal of this project is to develop and introduce MAMA into the market place.

Preproduction Plans

Before the completion of the final production design and article production, IMI will arrange, through its Research Program and its Apprenticeship and Training Program, extensive field trials of the prototype unit. Masons working in a wide variety of climates, differing building types, and differing masonry designs will be asked to use the device under observed conditions. The masonry contractors' organizations associated with IMI will be asked to evaluate the costs and productivity benefits that may emerge with full-scale use of the robotics.

Production Plans

The first steps in producing MAMA for use by the construction industry will be to reengineer the MAMA prototype for fabrication methods and incorporate modifications identified during the prototype testing. Some goals of the modifications include redesign for size and weight reduction, increase system ergonomics, and minimize production costs. Some modifications identified include simplification of the track by eliminating the slip joints and reducing the cross section where feasible, reducing cross section of the mounting arm, reducing the computer control from a multifunctional board to one designed specifically for MAMA, and changing the control handle to a pistol grip design. The production cost target is at or below $5,000 per unit. The initial production of MAMA is anticipated to begin during the last quarter of calendar year 1995; MAMA is expected to be commercially available for consumers by the end of the first quarter of calendar year 1996.

Marketing Plan

Marketing will be performed by IMI and their constituency and contractors. IMI's constituency includes the International Union of Bricklayers and Allied Craftsmen

(BAC) and the International Council of Employers of Bricklayers and Allied Craftsmen (ICE). MAMA will be marketed through IMI channels through these organizations. The IMI Apprenticeship and Training Program offers another excellent means for marketing the results of this research project into the industry.

IMI has invested masonry union time and money in the development of MAMA. As such, the commercial cost to consumers will reflect these investments. According to IMI plans, union members and union contractors will receive a discounted price on MAMA.

Expected Capabilities and Benefits of MAMA

The use of MAMA will reduce the human musculoskeletal strains and injuries in the mason population and the associated increased costs that result from the current masonry wall construction practices. Some of these associated increased costs include sick time losses on the job because of back strain and injury, high workmen's compensation insurance fees, and reduced productivity due to fatigue. MAMA will enhance the strength of skilled masons to handle heavy concrete masonry units and increase productivity by enabling masons to perform a greater volume of work without tiring, increase the working-life expectancy of skilled craftsmen, and provide the capability of placement of larger masonry units. These, in turn, will improve masonry construction competitiveness in the construction industry in the United States.

5 Conclusions and Recommendations

Conclusions

A mechanical assist can facilitate the lifting and placing of masonry block by masonry construction workers. MAMA takes advantage of robotic technologies to enhance the productivity of masonry craftsmen and to alleviate skeletal and muscular strains associated with lifting and handling heavy masonry units. MAMA is an article manipulator system that mounts on scaffold assemblies. It is capable of alignment compensation for scaffold nonalignment, limited movement about two vertical axes, and movement along a trolley track in a generally horizontal direction parallel to wall construction. It has a gripper for grasping heavy concrete masonry units and a control handle for raising and lowering them onto a wall being constructed.

The use of MAMA by block masons will enhance their strength and allow increased productivity through a greater volume of work without tiring and reduce construction costs through reduced lifting-related injuries and capability to place larger masonry units.

The use of MAMA is limited by the scaffolding design used by the contractor. MAMA was designed to attach to mast-type scaffolding. Mast-type scaffolding normally is used for construction of long walls and/or relatively high walls, up to 200 ft high. It is used in approximately 60 percent of the CMU construction in the United States. The remaining CMU construction uses metal frame-type scaffolding. MAMA, in its present configuration, cannot be used safely or efficiently with metal frame scaffolding.

Recommendations

MAMA should be used where applicable during heavy concrete masonry construction to reduce ergonomic hazards associated with CMU construction. Another design of MAMA should be developed for use with metal frame-type scaffolding.

Appendix A: MAMA Design Operational Capabilities and Performance Criteria

System Power Requirement	1/60/110 VAC 20 Amp, GFI Protection
Device Power Requirement	28 VDC, 50 Amps
Maximum Cycle Rate (MCR)	12 in./sec rate, 50 cycles/hour
Operators Station	Bihanded, right or left hand operation
Allowable Maintenance Time	0.02/Elapsed run time
Environmental Requirements	Outdoor, 30 to 110 °F, rain, snow, ice
Safety Requirements	IAW all OSHA/NIOSH/ANSI requirements
Mast/Platform Loading	750 lb
Maximum Mast Moment Loading	3000 ft/lb
Availability Time (AT)	0.97 time
Continuous Run Time (CRT)	08/16 hr
Operational Hour Life	20,000 hr (10-year life)
Enclosure/Housing	NEMA 4 min
Work Envelop	330° tore shape continuous track, dead space 60 in. diameter
Layout/Installation	Maximum flexibility/modular/expandable
Interfaces	IAW masons' operations and functions; and currently used equipment
Ergonomic Requirements	Accommodate all human masons to the 90th percentile

Appendix B: Scope of Work for Robotically Assisted Masonry Construction

1. Partners:
The International Masonry Institute (IMI)
823 Fifteenth Street, N.W.
Washington, D.C. 20005

U.S. Army Corps of Engineers
Construction Engineering Research Laboratories (USACERL)
P.O. Box 9005
Champaign, IL 61826-9005

2. Objective:

The masonry industry is of significant size. It is estimated to represent some $13 billion in annual volume, of which 40 percent is for direct labor costs, 40 percent for materials, and 20 percent for overhead and profit of contractors who work on the site. This project intends to increase the productivity of craftsmen by developing one or more devices (robots) designed to alleviate the skeletal and muscular strain associated with lifting and handling heavy masonry units.

The International Masonry Institute (IMI) was founded in 1970 as an instrument of service to union contractors and craftsmen in masonry and for advancing the interests of masonry.

Funded by contributions determined by the collective bargaining process, it continues to reflect the Specialized character and needs of this industry. IMI constituency includes the 105,000 members of the International Union of Bricklayers and Allied Craftsmen (BAC) and the 7000 firms that use their skills (organized through the International Council of Employers of Bricklayers and Allied Craftsmen [ICE]). The Apprenticeship and Training Program of the IMI is an addition to (not a replacement for) the efforts of some 500 locals of the BAC. These programs operate through five regions in the United States and Canada, and, with the support of the Agency for International Development, in Central America as well.

Masonry construction has a long history of strained backs and injuries for the skilled masons who build with brick, block, stone and marble. As the average age of craftsmen advances (it is now approaching an average working age of 55) there has been an unfortunate but parallel development in the weight (and often the size) of manufactured masonry units. The productivity of this sector of the U.S. construction industry would be greatly enhanced if one or more devices could be developed to alleviate the skeletal and muscular strain associated with lifting heavy units. The industry has experienced rapid increases in the cost of workers compensation insurance over the past decade due in large measure to back strain and injuries. Awards for back injuries on the job have been as high as $3 million per individual worker.

Robotic devices that are "extraskeletal" have been experimented with in military research programs to enhance the lifting capabilities of servicemen for handling munitions and other heavy objects. USACERL has recently developed a robotic device for disposing of explosive ordnances and had a project involving revetment automation on the Mississippi River.

This project, being proposed by IMI and USACERL, intends to provide for the technological transfer of military robotics work to the masonry industry by developing prototypical devices for use by masonry workers and providing field tests for such prototypes.

The technical work, undertaken by USACERL and their associated contractors, will result in prototypes which IMI will then be in a position, through its affiliation with the International Union of Bricklayers and Allied Craftsmen, to introduce into common usage.

3. Approach:

This project is planned to extend over a three-year period organized around three phases as described below:

Phase I: Project Definition (4 months)

A "Partnership" will be formed at the beginning of this phase consisting of three representatives of IMI and three technically qualified persons selected by USACERL. The team will be co-chaired by John Eberhard, the Principle Investigator for IMI, and Frank Kearney, Program Manager for USACERL. During this phase, the Partnership team will undertake a matrix analysis of the problem areas for masonry craftsmen (as measured in terms of health and safety issues) and cross-reference known technologies

that might be applied (technologies already advanced to the application stage, as contrasted with scientific developments or hypothetical technologies). A cost benefit analysis will then be used to assess which technologies show the most likely quick paybacks and associated benefits in terms of the productivity of this sector of the construction industry. The Partnership is biased from the outset towards the development of an “extraskeletal” robotic device which can be “worn” by a mason to assist in the lifting of units of up to 100 pounds with reduced muscular strain.

Phase II: Project Development (20-month time period)

During this phase the technical development would be done by USACERL, with the possible assistance of one or more private sector or university based teams in the robotics business. This activity would be integrated into the current USACERL program in automata, which includes the recently developed Explosive Ordnance Disposal robot and the Mississippi River revetment automation. Because the mechatronics involved in this proposed work is similar to these ongoing efforts, the technical leverage to be realized is significant.

IMI will provide ergonomic and technical data about a variety of field conditions to which the eventual devices might be subjected (e.g., working on scaffolding 150 feet in the air with 30 mph winds).

Within the 20-month period, the following tasks are anticipated:

1. Preliminary design of alternative devices (on paper) for evaluation by members of the IMI/USACERL Partnership.

2. Prototype design within the laboratory.

3. Limited field trials by experienced craftsmen whose services will be organized by IMI.

4. Redesign of the prototype based on experience from trials.

5. Development of working prototype for full field investigation.

6. Technical discussions with prospective manufacturers and masonry contractors regarding the economic feasibility of prototype concepts.

Phase III: Prototype Production and Testing (12 months)

Based on the results of Phase II, USACERL and their associated contractors will design and produce one or more working prototypes of the selected device(s). The IMI will then arrange, through its Research Program and its Apprenticeship and Training Program, extensive field trials of the prototype units. Masons working in a wide variety of climates, differing building types, and differing masonry designs would be asked to use the device(s) under observed conditions. The masonry contractors organization (e.g., ICE) associated with IMI would be asked to evaluate the costs and productivity benefits likely to emerge with full scale use of the robotics.

Adjustments to the device(s) will be incorporated into final prototype designs by USACERL and their associated contractors. Patent applications will be prepared and processed. Licensing agreements will be written.

Post Project Phase: Production and Diffusion

Based on the work done during the program outlines above, it is anticipated that one or more firms will be licensed to begin production of the device(s) developed by the Partnership.

The IMI Apprenticeship and Training Program offers an excellent means for diffusing the results of this research project into the industry. No funds are required from the project budget for this phase, but a significant factor in the likely success for technology transfer is represented by the mechanism of this IMI capability.

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